C23 Hazards of Volcanic Eruption to Aviation

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The goal of this presentation is to provide information on both the chemical and physical properties of the ash plume from Eyjafjoll volcano. Information on the potential and actual hazards of ingesting volcanic particles into modern jet-turbine engines will be considered.

This presentation will impact the forensic science community by presenting recently determined scientific data on the chemical and physical nature of volcanic ash. That information will be valuable in litigating mechanical failures in aircraft jet engines.

Commercial aviation has been striving in recent years to improve the efficiency of their jet-turbine engines, especially after fuel costs have continued to sky-rocket. In order to offset the high cost of fuel, aircraft engine manufacturers have been striving to produce jet turbines that are more thermodynamically efficient.

The efficiency of a jet-turbine engine equals $T_1 - T_2 / T_1$ where T_1 and T_2 are the absolute temperatures in the hot chamber and cold chamber respectively. The upper temperature limit in the combustion gas is dictated by the maximum temperature that the high-temperature turbine blades were designed to operate in. If the high temperature turbine blades are exposed to higher than the maximum design temperature, the blade alloy will be subjected to an "overtemp" condition, in which incipient melting of grain boundary metal will occur, and carbon will be solutioned in the metal grains. Incipient melting in superalloys usually starts at about 100°C below the alloy's actual melting point.

In order to obtain a more efficient engine performance, the blades in the first two high-pressure turbine discs are fabricated with hollow cores and numerous small air holes, approximately 1mm in diameter. Those small holes can direct a layer of highly pressurized cold air across the airfoil of those blades and thus permit the turbine blades to safely operate in combustion gas at an appreciably higher temperature. Unfortunately, if those engines are operated in dust-ridden conditions, such as sand storms or high concentrations of volcanic ash, those small air holes in the blade's airfoil can easily become blocked. Should blockage occur, it will then cause the operating temperature of HPT-1 and HPT-2 turbine blades to rapidly rise to an unsafe operating level.

Particulate matter, that is larger than that which can either pass through or block air holes in the turbine blades, can do appreciable damage to metal parts in jet turbine engines and lead to severe structural damage.

High-temperature oxidation of superalloys in "clean" combustion gas will produce mixed oxides of their major metal components, which are usually nickel and chromium. When the combustion gas carries extraneous gas and/or low melting point particulate material to the heated surface, a deposit-modified oxidation process will occur: called "hot corrosion."

To characterize the ash plume from the Eyjafjoll volcano, which erupted in Southern Iceland from April 14, 2010 to May 23, 2010, a sampling of volcanic ash was collected on April 30, 2010 from Thorvaldseyri Farm, which is located approximately 40 kilometers west of the city Vik. The actual eruption site was approximately 4.5 kilometers north of the farm.

Approximately 29 grams of volcanic ash was sieved and analyzed using a combination of polarized light microscopy (PLM), scanning electron microscopy-energy dispersive x-ray spectrometry (SEM-EDS) and transmission electron microscopy coupled with select area electron diffraction an energy dispersive x-ray spectrometry (AEM). PLM examination of the <63µm fraction reveals abundant volcanic glass fragments with mineral inclusions. The glass ranges from frothy colorless pumice particles to brown fragments, some exhibiting vesicular texture. Many fragments are magnetic, apparently due to the presence of microscopic inclusions of magnetite; ilmenite and/or titanomagnetite are also indicated by SEM-EDS analysis of inclusions in the glass. Plagioclase, olivine and clinopyroxene are present as individual grains and as inclusions within the glass. SEM and AEM analysis were used to support the PLM analysis.

Volcanic Ash, Jet Engine, Microscopy

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